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(54) Gas turbine rotor blade tip cooling device

Kühlung für die Blattspitzen einer Turbine

Refroidissement des extrémités des aubes de turbine

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Description

[0001] The present invention relates to a gas turbine rotor blade tip cooling device in a gas turbine hollow cooled rotor blade, comprising a plurality of first cooling holes communicating between a cooling air passage in the blade and the outside surface of a tip squealer portion. Such a device is shown in US-A-5 261 789.

[0002] Fig 9 of the accompanying drawings is a perspective view showing one example of a conventional gas turbine hollow rotor blade. In the figure, cooling air (supplied by a compressor) flowing into a blade from the bottom of a blade root 11 flows in the arrow-marked direction to cool the rotor blade. Specifically, the cooling air, flowing into the blade from the leading edge side 12A flows through a winding passage having fins 13 to cool the blade, flows out of the blade through a hole A in the blade top at which a tip squealer (thinning) 14 is provided, and joins with the main gas flow which rotates the turbine. The cooling air, flowing into the blade from the trailing edge side 12B, flows through a cooling passage provided with fins 13 in the arrow-marked direction, cools the blade trailing edge by means of pin fins 15, flows out of the blade through holes or slits 8, and joins with the main gas flow.

[0003] Fig. 10 is a plan view of the rotor blade tip of Fig. 9. The tip squealer 14 is formed in a thin wall shape along the blade profile to provide measures against contact with a circular casing ring.

[0004] In a high-temperature gas turbine as described above, the gas turbine rotor blade must withstand high temperatures. Especially at the blade tip portion, the tip squealer 14 is provided to protect the blade from damage caused by the contact with a ring segment.

[0005] However, the tip squealer 14 serves as a heat transfer fin at the same time. Therefore, the temperature of the tip squealer 14 is increased greatly by receiving heat from high-temperature gas which rotates the turbine, which often results in high-temperature oxidation.

[0006] Also, the lower face of a tip cap at the trailing edge portion is usually formed thicker than other portions because the blade thickness is small. The thicker the tip cap is, the higher the temperature is.

[0007] The present invention seeks to solve the above problems. Accordingly, an object of the present invention is to provide a gas turbine rotor blade tip cooling device in which the high-temperature oxidation of the tip portion caused by abnormally increased temperature is prevented, and the reliability can be improved without adverse effect on the aerodynamic characteristics of the blade.

[0008] In accordance with the present invention, there is provided a gas turbine rotor blade tip cooling device in a gas turbine hollow cooled rotor blade, comprising a plurality of first cooling holes communicating between a cooling air passage in the blade and the outside surface of a tip squealer portion in a range from the leading edge on the pressure side of the blade to an intermediate position at the trailing edge portion on the pressure side and a plurality of second cooling holes communicating between said cooling air passage in the blade and a portion at which the tip squealer portion on the pressure side of a tip cap is lacking.

[0009] Preferably, the thickness of said tip cap at the portion at which the tip squealer portion on the pressure side of the tip cap is lacking is nearly the same as the thickness of said tip cap at other portions.

[0010] Advantageously, the diameter of each first cooling hole lies in the range from 0.5mm to 2.0mm.

[0011] Preferably, said device further includes a plurality of third cooling holes communicating between said cooling air passage in the blade and the tip cap surface in the vicinity of the inner surface of a tip squealer portion on the suction side.

[0012] Advantageously, the diameter of each said third cooling hole lies in the range from 0.5mm to 2.0 mm.

[0013] Advantageously, the height of the tip squealer portion lies in the range from 0.1 mm to 5.0 mm.

[0014] Since the high-temperature gas at the rotor blade tip flows through the clearance between the tip and a ring segment from the pressure side to the suction side, the tip squealer portion on the pressure side is film cooled by forming the cooling holes at the tip squealer on the pressure side and at a position in the vicinity of the suction side of a tip cap. The cooling holes in the vicinity of the suction side of the tip cap contribute to convection cooling, providing effective tip cooling.

[0015] Because the tip squealers provided on the pressure side and on the suction side are film cooled, by which the temperature of tip does not become abnormally high, the cause of high-temperature oxidation can be alleviated.

[0016] The flow at the turbine tip clearance is produced from the pressure side 40 to the suction side 41 by the difference in pressure between the pressure side 40 and the suction side 41 of the tip (as illustrated in Fig. 4). In the conventional tip, this flow is produced as shown at the left-hand part of Fig. 5. In the present invention, as shown at the right-hand part of Fig. 5, the tip squealers 42 and 43, which are hot, are covered by a cooling air film of the flow indicated by the arrow in the figure, by which the turbine can be protected from high-temperature gas. Also, the cooling holes 5 at the tip squealer on the pressure side are provided in an oblique direction from the interior of blade. Therefore, the cooling air passing through these holes can join with the flow at the tip clearance smoothly. The length of the cooling hole is large as compared with a known cooling hole 5' shown in FIG. 6, which was disclosed in United States Patent No. 5,261,789, so that heat exchange from the inside surface of cooling hole is promoted, which provides excellent cooling properties.

[0017] The improvement provided by the present invention does not change the tip profile, so that the hydrodynamic characteristics are not affected.

[0018] Since the tip squealer is formed of low height, the tip squealer at trailing edge portion Y on the pressure side is lacking, cooling holes being provided at this portion, and the thickness of the tip cap at this portion is nearly the same as that of the tip cap at other portions, the temperature increasing phenomenon, which is found in the conventional rotor blade, and is caused by large tip squealer height and thick tip cap, can be avoided.

[0019] Conventionally, the height h' (FIG. 7) of tip squealer portions 1 and 2 has been large, so that the heat input from the gas side has been high. In the present invention, the height (h in FIG. 8) is small, so that the heat input from the gas side can be decreased.

[0020] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

[0021] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

FIG. 1 is a plan view of a tip cooled rotor blade in accordance with one embodiment of the present invention;
FIG. 2 is a sectional view taken along the line X-X of FIG. 1;
FIG. 3 is a sectional view taken along the line Z-Z of FIG. 1;
FIG. 4 is a perspective view schematically showing the upper part of a tip cooled rotor blade to which the present invention is applied;
FIG. 5 is a schematic sectional view comparing a tip cooled rotor blade having no cooling hole 5 and a tip cooled blade having a cooling hole 5;
FIG. 6 is a schematic sectional view showing a tip cooled rotor blade of United States Patent No. 5,261,789;
FIG. 7 is a schematic sectional view showing a tip squealer of a conventional tip cooled rotor blade;
FIG. 8 is a schematic sectional view showing a tip squealer of a tip cooled rotor blade in accordance with the present invention;
FIG. 9 is a perspective sectional view showing one example of a conventional hollow cooled rotor blade; and
FIG. 10 is a plan view of the hollow cooled rotor blade shown in FIG. 9.

[0022] In the embodiment shown in Figs 1 to 3, a tip squealer 1 on the pressure side of a rotor blade and a tip squealer 2 on the suction side are provided along the plan shape of the blade. These tip squealers 1 and 2 are formed lower than those of the conventional rotor blade, the height (h) thereof being 0.1 mm to 5.0 mm.

[0023] Therefore, a tip squealer of a height (h) of about 5.0 mm is usually provided in a thin wall shape along the blade profile to provide measures against contact with a circular casing ring. In this embodiment of the present invention, the height of tip squealer 1, 2 from a tip cap (h in FIG. 2) is as small as 0.1 mm to 5.0 mm, preferably 0.1 mm to 1.5 mm, by which the portion serving as a heat transfer fin receiving heat from high-temperature gas can be decreased while maintaining the measures against the contact with the circular ring of casing, so that the increase in temperature of rotor blade can be prevented. If the height h is less than 0.1 mm, manufacturing error cannot be accommodated. The tip squealer 1 on the pressure side is provided with cooling holes 3 as shown in FIG. 2, which is a sectional view taken along the line X-X of FIG. 1.

[0024] In the vicinity of the suction side of the tip cap 4, cooling holes 5 are made as shown in FIGS. 1 and 2. The diameter of the cooling holes 3, 5 is about 0.5 mm to 2.0 mm. If the diameter is less than 0.5 mm, the hole can-become clogged with dust, so that a diameter from 0.1 mm to 2.0 mm is effective in terms of heat transfer and thermal stress. If the diameter exceeds 2.0 mm, damage may be caused by drilling.

[0025] In a rotor blade having such a cooling configuration, at the trailing edge portion on the pressure side, which is relatively less affected by contact with the circular ring of casing, the tip squealer 1 on the pressure side is lacking as shown by portion Y in FIG. 1. At this portion, cooling holes 6 are made toward the tip direction of the rotor blade. At portion Y, at which the tip squealer on the pressure side is lacking, the thickness of the tip cap 4 is nearly the same as that of the tip cap at other portions as shown in FIG. 3, which is a sectional view taken along the line Z-Z of FIG. 1. Therefore, the trailing edge portion of the rotor blade does not form a sharp end portion, at which the blade thickness is thin, in the manner of the trailing edge portion of the conventional rotor blade.

[0026] Virtual line portion D shows the thick shape of the tip cap at the trailing edge portion of the conventional rotor blade. Because the tip squealer is lacking at this portion, the portion serving as a heat transfer fin which receives heat from high-temperature gas is small. Also, because the tip cap has a uniform thickness, not only the temperature of this portion does not increase but the increase in rotor blade temperature can effectively be prevented by a synergistic effect with the cooling air flowing through the cooling holes 6 provided at this portion.

[0027] As described in detail above, according to the tip cooling device for gas turbine rotor blade in accordance with the present invention, the function of the tip squealer as a heat transfer fin can be inhibited by the

cooling air flowing through the cooling holes provided at this portion, so that the temperature of the tip portion does not become abnormally high, alleviating the cause of high-temperature oxidation.

[0028] The cooling holes in the tip squealer on the pressure side, which are provided in an oblique direction from the interior of the blade, do not change the shape of the tip squealer provided along the blade profile. Therefore, the aerodynamic characteristics of the blade are not affected, so that effective cooling can be effected.

[0029] Also, the temperature increasing phenomenon due to the presence of the thick portion of the tip cap, which is found in the conventional rotor blade, can be avoided, so that the effect of contributing to the improved reliability of the gas turbine is very great due to the synergistic effect with the cooling performed by the cooling holes.

[0030] Reference is hereby directed to our parent EP-A- 0684364 which describes and claims a gas turbine rotor blade tip cooling device in a gas turbine hollow cooled rotor blade, comprising a plurality of first cooling holes communicating between a cooling air passage in the blade and the outside surface of a tip squealer portion in a range from the leading edge on the pressure side of the blade to an intermediate position at the trailing edge portion on the pressure side, a plurality of second cooling holes communicating between said cooling air passage in the blade and a portion at which the tip squealer portion on the pressure side of a tip cap is lacking, and a plurality of third cooling holes communicating between said cooling air passage in the blade and the tip cap surface in the vicinity of the inner surface of a tip squealer portion on the suction side of the blade.

Claims

1. A gas turbine rotor blade tip cooling device in a gas turbine hollow cooled rotor blade, comprising a plurality of first cooling holes (3) communicating between a cooling air passage in the blade and the outside surface of a tip squealer portion in a range from the leading edge on the pressure side of the blade to an intermediate position at the trailing edge portion on the pressure side and a plurality of second cooling holes (6) communicating between said cooling air passage in the blade and a portion at which the tip squealer portion on the pressure side of a tip cap is lacking.

2. A gas turbine rotor blade tip cooling device according to claim 1, wherein the thickness of said tip cap at the portion at which the tip squealer portion on the pressure side of the tip cap is lacking is nearly the same as the thickness of said tip cap at other portions.

3. A gas turbine rotor blade tip cooling device according to claim 1 or 2, wherein the diameter of each first cooling hole (3) lies in the range from 0.5mm to 2.0mm.

Patentansprüche

1. Kühlvorrichtung für Schaufelspitzen eines Gasturbinenrotors in einer hohlgekühlten Rotorschaufel einer Gasturbine, umfassend eine Vielzahl erster Kühllöcher (3), die zwischen einem Kühlluftdurchgang in der Schaufel und der Außenfläche eines Spitzenverschleißabschnitts in einem Bereich von der Führungskante auf der Druckseite der Schaufel zu einer Zwischenposition an dem Hinterkantenteil auf der Druckseite kommunizieren, und eine Vielzahl zweiter Kühllöcher (6), die zwischen dem genannten Kühlluftdurchgang in der Schaufel und einem Teil kommunizieren, an dem der Spitzenverschleißabschnitt auf der Druckseite einer Spitzenkappe fehlt.

2. Kühlvorrichtung für Schaufelspitzen eines Gasturbinenrotors nach Anspruch 1, bei der die Dicke der genannten Spitzenkappe an dem Teil, an dem der Spitzenverschleißabschnitt auf der Druckseite der Spitzenkappe fehlt, beinahe die gleiche wie die Dikke der genannten Spitzenkappe an anderen Teilen ist.

3. Kühlvorrichtung für Schaufelspitzen eines Gasturbinenrotors nach Anspruch 1 oder 2, bei der der Durchmesser jedes ersten Kühllochs (3) in dem Bereich von 0,5 mm bis 2,0 mm liegt.

Revendications

1. Un dispositif de refroidissement de bout d'aube de rotor de turbine à gaz dans une aube de rotor à passages de refroidissement dans une turbine à gaz, englobant une pluralité de premiers trous de refroidissement (3) qui communiquent entre un passage d'air de refroidissement dans l'aube et la surface extérieure d'une partie d'une bande perdue dans une plage comprise depuis le bord d'attaque sur le côté pression de l'aube jusqu'à une position intermédiaire en la partie du bord de fuite du côté pression, et une pluralité de deuxièmes trous de refroidissement (6) qui communiquent entre ledit passage d'air de refroidissement dans l'aube et une partie en laquelle la partie de la bande perdue manque sur le côté pression de la chape de bout d'aube.

2. Un dispositif de refroidissement de bout d'aube de turbine à gaz selon la revendication 1, dans lequel l'épaisseur de ladite chape de bout d'aube, en la

partie à laquelle manque la partie de bande perdue du côté pression de la chape de bout d'aube, est presque identique à l'épaisseur de ladite chape de bout d'aube en d'autres parties.

3. Un dispositif de refroidissement de bout d'aube de turbine à gaz selon la revendication 1 ou 2, dans lequel le diamètre de chaque premier trou de refroidissement (3) est compris dans la plage de 0,5 mm à 2,0 mm.

FIG. 1

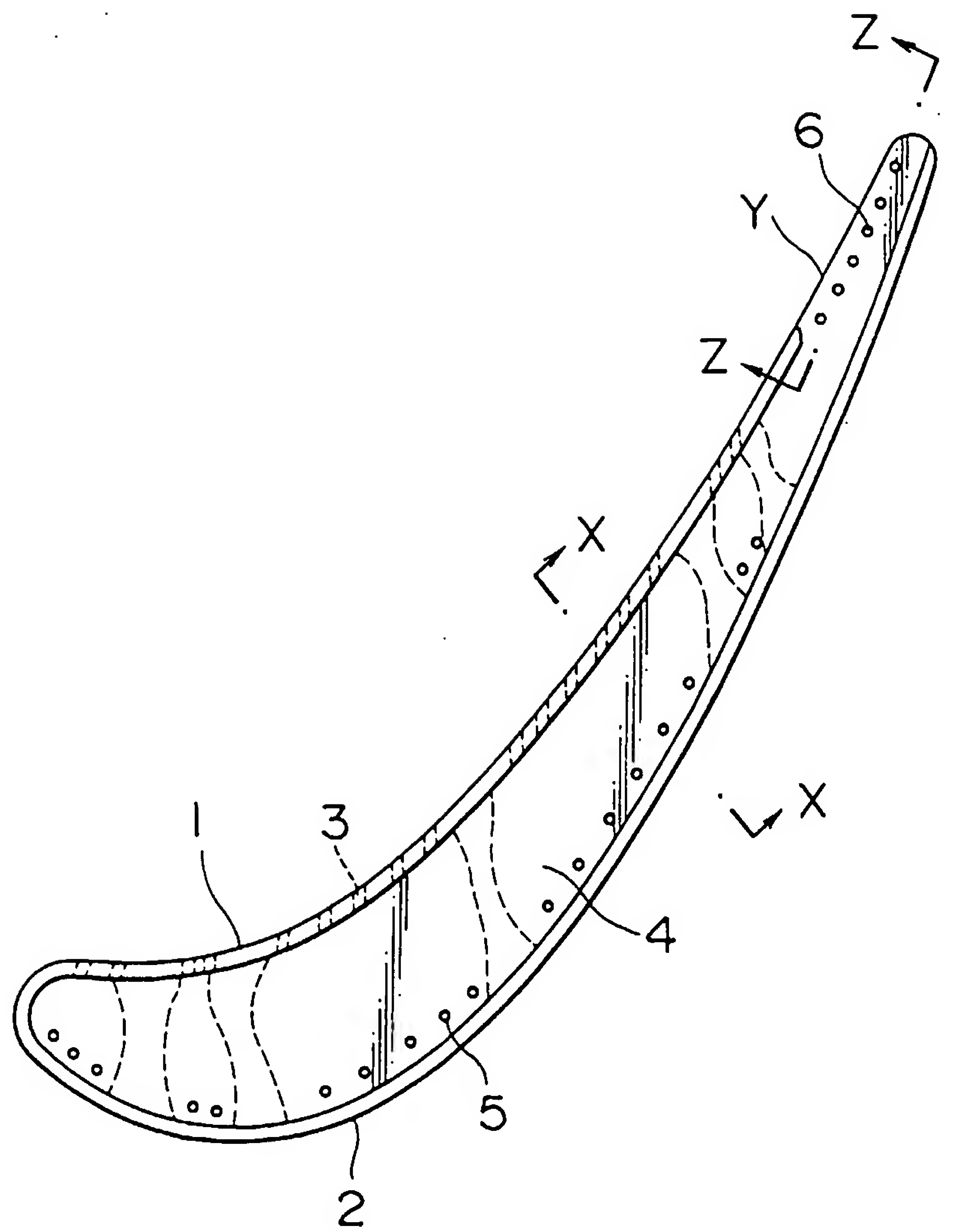

FIG. 2

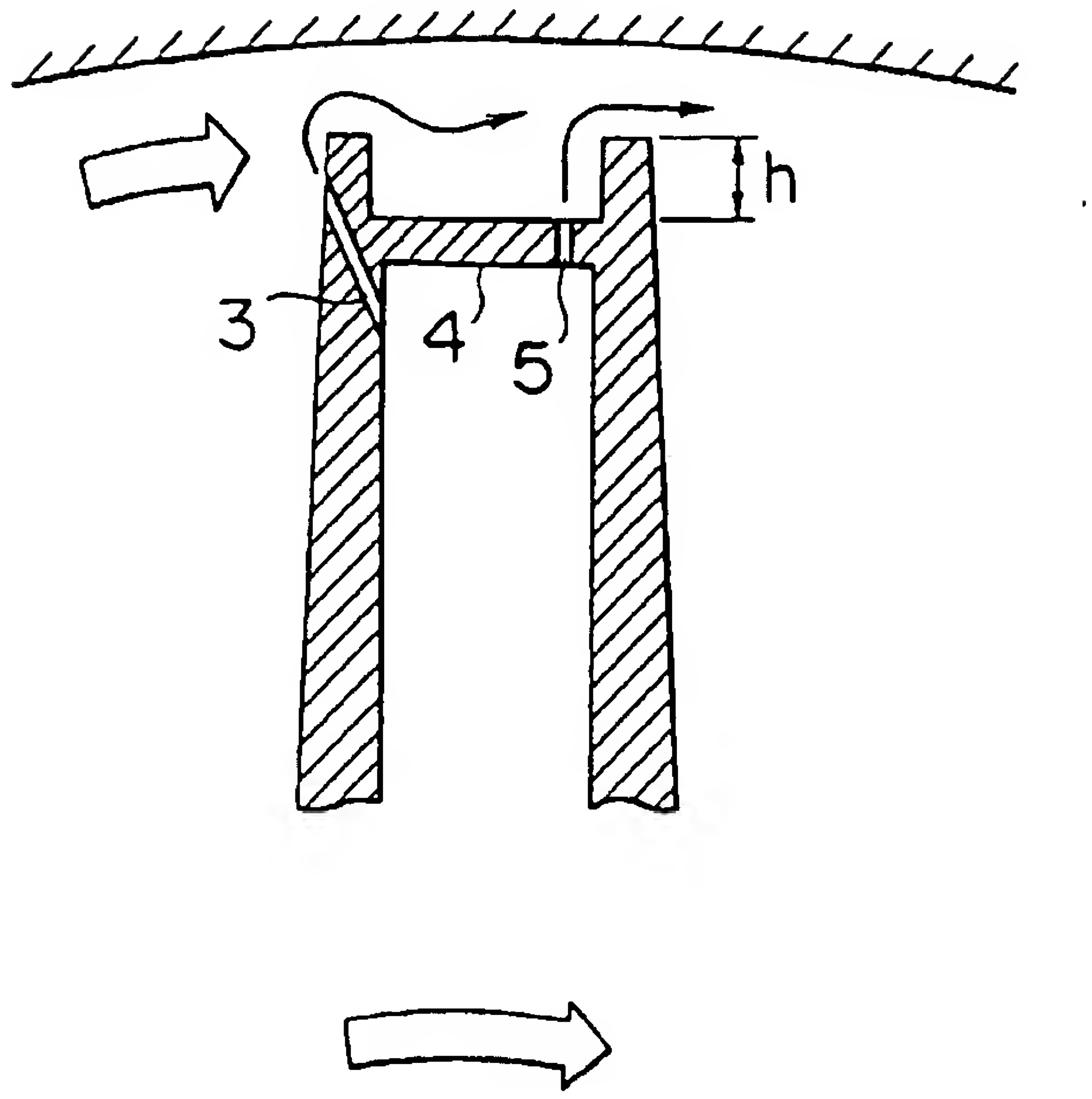

FIG. 3

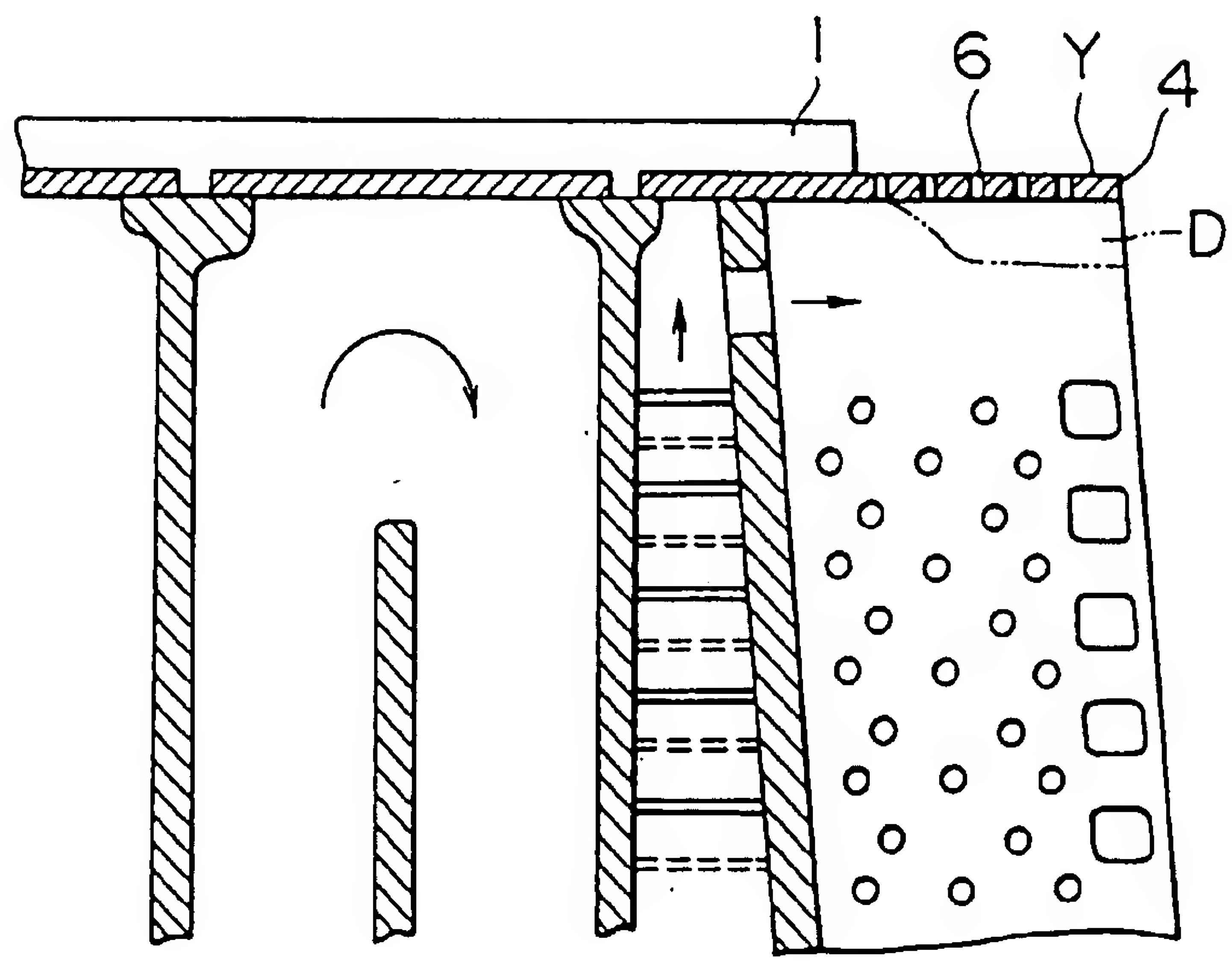

FIG. 4

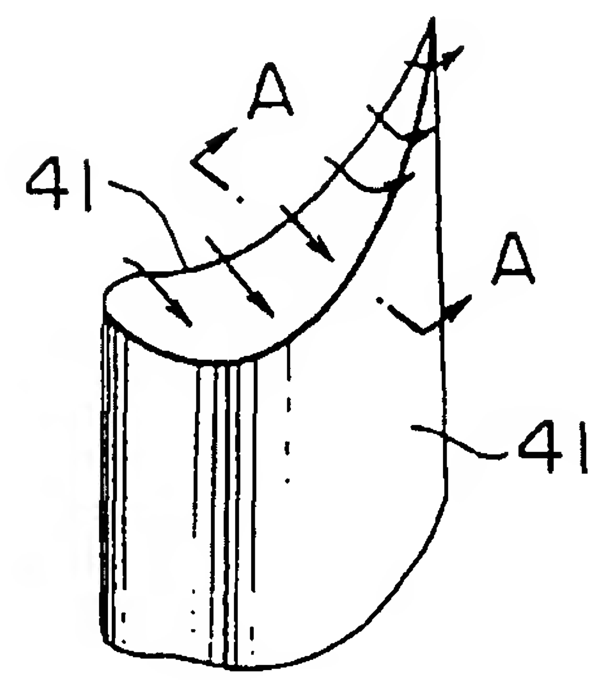

FIG. 5

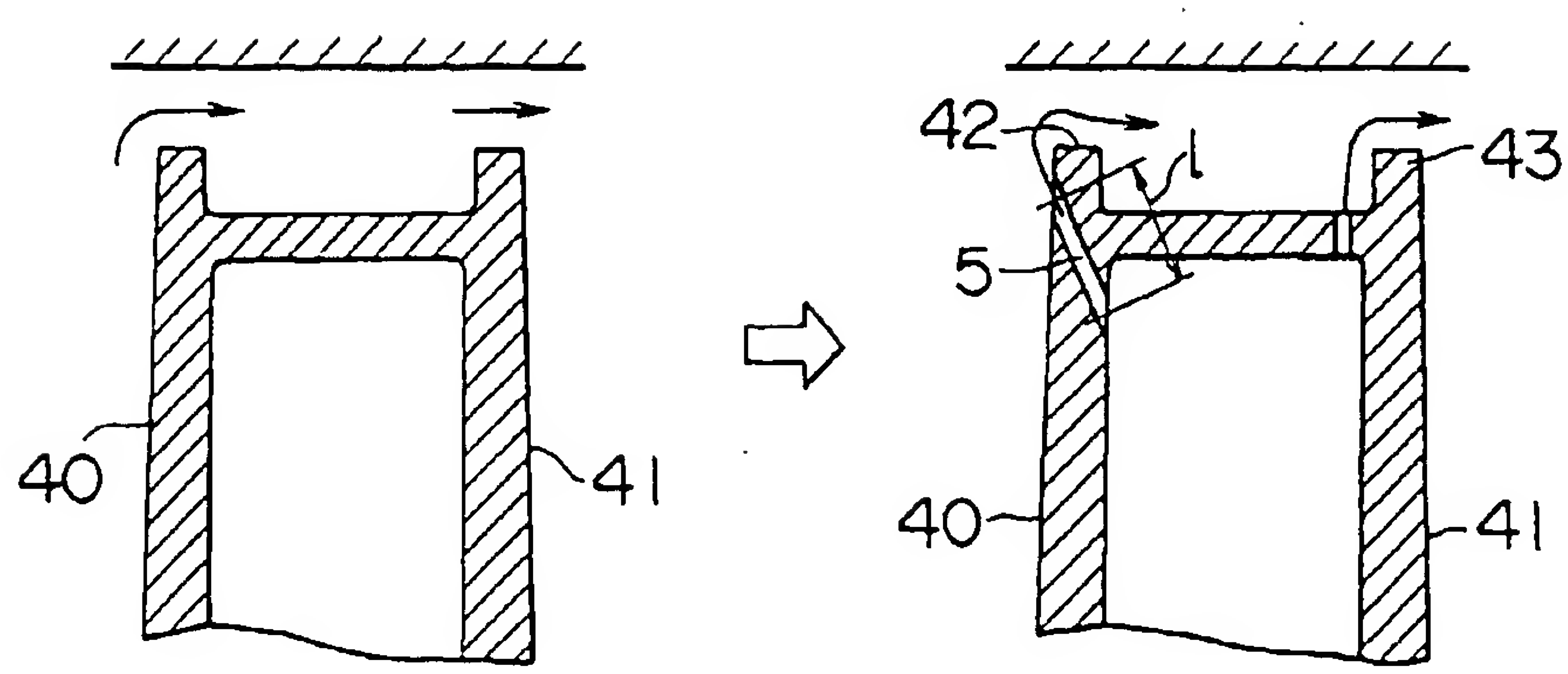

FIG. 6

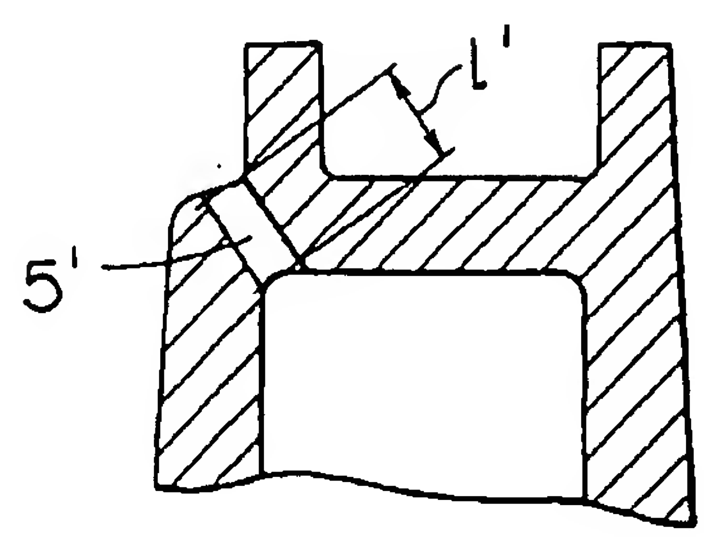

FIG. 7

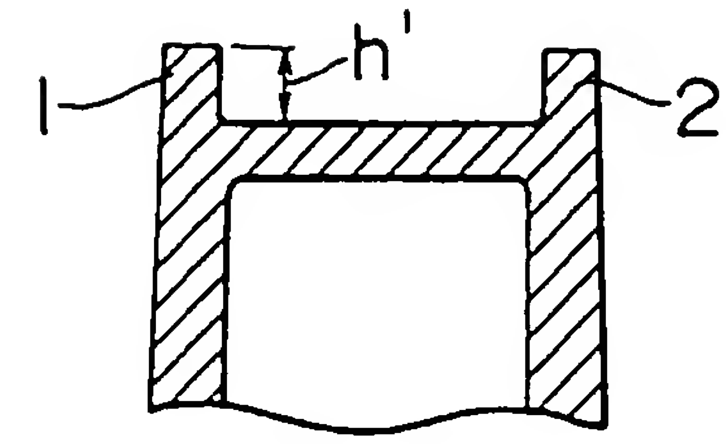

FIG. 8

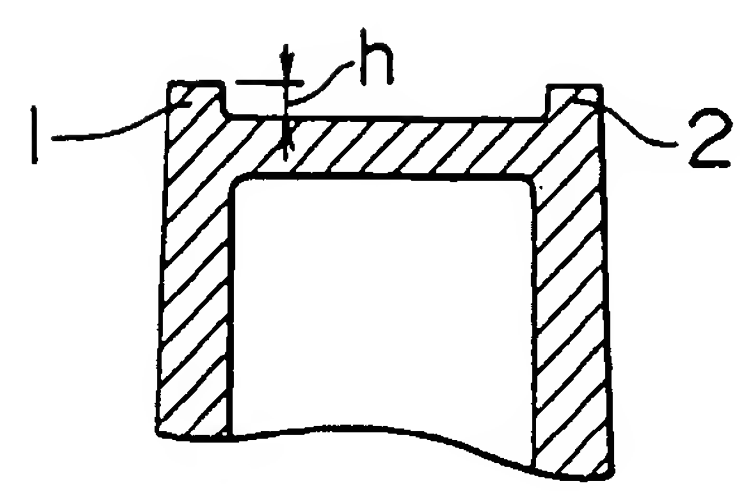

FIG. 9

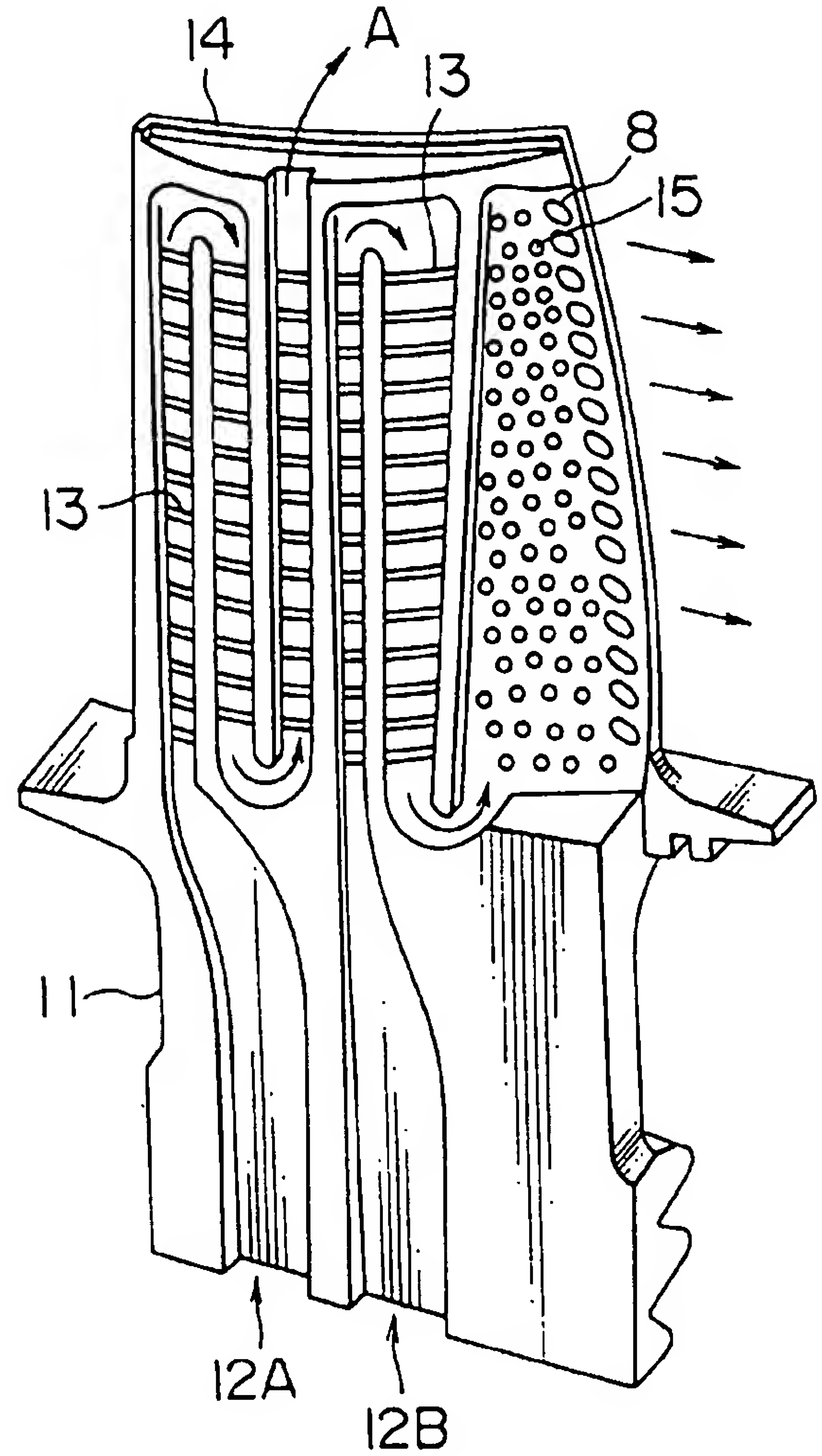

FIG. 10